THE APPLICATION OF ECOSYSTEM SERVICES IN HIGHER EDUCATION PLANNING: VERY HIGH RESEARCH INSTITUTES

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THE APPLICATION OF ECOSYSTEM SERVICES IN HIGHER EDUCATION PLANNING: VERY HIGH RESEARCH

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This thesis is dedicated to higher education institutions across the United States. It is my hope that this work, which combines practical experience with applied research, may be a small building block meant to connect the broader body of planning knowledge with actions applied on campuses.

I wish to show my gratitude to my thesis committee members, Dr. William Drummond and Vice Chancellor Sandra Neuse, as well as my advisor, Dr. Brian Stone. Without their guidance and encouragement, I certainly would not have developed anything useful.

I was also very fortunate to act as an applied research shepherd to a group of research engineers in the Aerospace Systems Design Lab at Georgia Institute of Technology during the time that I was researching and writing this paper. The team, led by Dr. Dimitri Mavris, included Dr. Scott Duncan, Dr. John Lewe and Dr. Michael Balchanos. Hearing how these brilliant minds approached data and information analysis from a systems perspective certainly helped influence my method.

I would be remiss not to acknowledge the years of research on ecosystem services and planning that have come before me. I once overheard a very smart man explain that each individual study in academic research should contribute to an overall body of knowledge -essentially the whole is worth more than the sum of its parts. (Thanks Dr. John Taylor!) I certainly hope this work adds a few grains of sand to the mountain. Of course, seminal works by Ian McHarg and Aldo Leopold set the stage for any consideration of environmental systems and stakeholder values to be applied to planning.

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SUMMARY

The question this study aims to answer is "Are ecosystem services being utilized within campus planning frameworks to address human health and environmental performance?" and then –"If yes- is there an effective measurement plan associated with said services to measure success?"

To answer this question, an extensive literature review was conducted to understand the current state of ecosystem services in planning in general, and planning in higher education. Through the review, it is established that including ecosystem services in planning requires a more intense level of valuation, beyond economics. Also, the most successful plans include stakeholder engagement during goal setting. Measuring the outcomes of plans is an emerging best practice in the planning industry.

Next a plan evaluation index was developed and applied to a sample of very high research higher education planning documents. The evaluation uncovered that while certain R1 campuses are broadly including ecosystem services in their planning efforts, they have not yet mastered the implementation or measuring of these services.

The ultimate goal of this effort is to connect research to practice. If the theory and existing analyses are better understood, then practical methods should be identified to apply to higher education planning; methods that will leverage environmental performance to positively impact human and broader ecological health.

CHAPTER 1. INTRODUCTION

What makes a good university plan? Should higher education be concerning itself with incorporating ecological imperatives into their planning efforts? In this age of the Anthropocene, when hundreds of thousands of young people and billions of research dollars are being directed through doctoral institutes, the answer is unequivocally YES. This paper is an effort to gain a broad understanding of ecosystem services in planning and then to evaluate whether a sampled sub-set of higher education institutions is addressing ecological imperatives through their planning initiatives within the United States.

The question this study aims to answer is, “Are ecosystem services being utilized within campus planning frameworks to address human health and environmental performance?” and then –“If yes- is there an effective measurement plan associated with said services to measure success?” To answer this question, an extensive literature review was conducted to understand the current state of ecosystem services in planning. Next a plan evaluation index was developed and applied to a sample of higher education planning documents.

As a professional working in the administrative realm of higher education, my goals are to identify practical methods to apply to higher education planning; methods that will leverage environmental performance to positively impact human and broader ecological health.

1.1 Purpose and Significance of Study

The purpose of this paper is to describe and analyze the use of ecosystem services as a planning tool on college and university campuses in the United States. The literature revealed that due to current social imperatives such as sustainable development, it is likely that including ecosystem services in planning documents will continue. What is not clear is how those inclusions can be evaluated for effectiveness. Without evaluating plans and developing policies which enable plan goals to be realized, planning professionals are not closing the loop of planning.

As explained by Berke and Godschalk:

> "The essence of a profession, such as city and regional planning, is its capacity to set and enforce high standards of practice. Good practitioners learn from reflecting on their experience and on the quality of their work; their reflection is assisted by professional norms of good practice. Over time, this professional learning shapes criteria for best practices in land use planning as well as other areas of planning" (2009, 228).

My hope is that through the outcomes identified in this qualitative research, some best practices emerge. If my findings inspire even a few planning practitioners at higher education institutions to be more thoughtful in the application and measurement of ecosystem services in future plans, then this work can be considered a success.

1.2 Structure of Paper

This paper summarizes the research literature on the following subjects: the background and definitions of ecosystem services; how ecosystem services are measured; the relationship between ecosystem services, human health and ecological performance and how ecosystem services are applied in planning. The application review includes a comparison of resiliency and sustainability planning concepts; the state of planning with ecological objectives in higher education and, overall, what makes a good plan.

The key concepts and criteria of planning with ecosystem services identified in the literature were then categorized and developed into a preliminary index. The index was applied to eight selected sets of campus planning documents and associated plan supplements from doctoral higher education institutes in the United States classified as R1, (very high research activity), by the Carnegie Classification.

The paper concludes with recommendations for future directions to be explored in higher education planning, as well as expanded evaluations.

CHAPTER 2. LITERATURE REVIEW

2.1 History of Ecosystem Services

Ian McHarg's seminal book, "Design with Nature" provided early examples of how to consider ecological benefits in land-use planning and design decisions without the explicit label of ecosystem services (1969). He later wrote recommendations for conducting crude landscape suitability analyses by ranking ecological factors. The shaded Mylar sheets layered over a map would result in darker areas of land being of higher value. McHarg's evaluation process, while imprecise and incomplete by his own admission, represents an early precursor of ecosystem service analysis (Nelson et al. 2009).

Ecosystem services are the ecological characteristics, functions or processes that directly or indirectly contribute to human wellbeing; essentially the benefits that people derive from functioning ecosystems (Costanza et al. 1997). While McHarg's work remains an authoritative contribution at the intersection of the ecology, planning, landscape architecture, and architecture fields (Steiner 2006), the concept of planning with ecosystem services, both applied and in research, has greatly expanded since 1969.

In the 1980s the ecosystem services concept was developed to bridge the natural and social sciences and position ecosystem functions and structures as beneficial to society (Ehrlich and Ehrlich 1981). In the previous and following decades, as alarming environmental changes were coming to light, ecosystem services emerged as a concept intended to facilitate collaborative management and promote benefits of ecology (Torkar and Krašovec 2019). A shifting point in the interest in ecosystem services happened when, after producing an edited book on ecosystem services, Robert Costanza proposed the idea to synthesize all the information into a shared framework for assessing the values of ecosystems while incorporating those values into market decisions (1997). After this early attempt to value of the world's ecosystem services, a large number of publications and articles began appearing, either challenging or complementing the initial work to explain the benefits of ecosystems to human society (Costanza et al. 2017). It is generally agreed that the concept of ecosystem services is anthropocentric and utilitarian (Fisher and Brown 2014).

In 2001, the United Nations Environmental Program convened over 1,350 experts from 95 countries to review the state of Earth's ecosystems and the consequences of human activity on environmental functions (MEA 2005). This effort resulted in the Millennium Ecosystem Assessment. Since that time, thousands of articles have been published contributing to the body of knowledge that is ecosystem services.

2.2 Defining Ecosystem Services

To develop a full inventory of ecosystem services, an understanding of ecosystem functions is required. It is from these fundamental ecosystem functions that ecosystem services are derived. Ecosystem functions include biotic, bio-chemical and abiotic processes, within and between ecosystems (Brussard, Reed, and Tracey 1998, Turner, Lefler, and Freedman 2005). Ecosystem functions and services are often interdependent and represent joint products of the ecosystem, supporting human benefits (Costanza et al. 1997).

Many attempts have been made to list ecosystem services. In a non-exhaustive list, de Groot et al (see Table 1 below) identified approximately twenty ecosystem services that outlined habitat, regulation, aesthetic and recreational benefits to humans (2002). Figure 1 was developed by the Millennium Ecosystem and it illustrates the combinations of services provided to humans from ecosystems, across a landscape.

Table 1: Functions, Goods and Services of Natural and Semi-Natural Ecosystems

	Functions	Ecosystem processes and components	Goods and services (examples)
	Regulation Functions	*Maintenance of essential ecological processes and life support systems*	
1	Gas regulation	Role of ecosystems in bio-geochemical cycles (e.g. CO_2/O_2 balance, ozone layer, etc.)	1.1 UVb-protection by O_3 (preventing disease). 1.2 Maintenance of (good) air quality. 1.3 Influence on climate (see also function 2.)
2	Climate regulation	Influence of land cover and biol. mediated processes (e.g. DMS-production) on climate	Maintenance of a favorable climate (temp., precipitation, etc) for, for example, human habitation, health, cultivation
3	Disturbance prevention	Influence of ecosystem structure on dampening env. disturbances	3.1 Storm protection (e.g. by coral reefs). 3.2 Flood prevention (e.g. by wetlands and forests)
4	Water regulation	Role of land cover in regulating runoff & river discharge	4.1 Drainage and natural irrigation. 4.2 Medium for transport
5	Water supply	Filtering, retention and storage of fresh water (e.g. in aquifers)	Provision of water for consumptive use (e.g.drinking, irrigation and industrial use)
6	Soil retention	Role of vegetation root matrix and soil biota in soil retention	6.1 Maintenance of arable land. 6.2 Prevention of damage from erosion/siltation
7	Soil formation	Weathering of rock, accumulation of organic matter	7.1 Maintenance of productivity on arable land. 7.2 Maintenance of natural productive soils
8	Nutrient regulation	Role of biota in storage and re-cycling of nutrients (eg. N,P&S)	Maintenance of healthy soils and productive ecosystems
9	Waste treatment	Role of vegetation & biota in removal or breakdown of xenic nutrients and compounds	9.1 Pollution control/detoxification. 9.2 Filtering of dust particles. 9.3 Abatement of noise pollution
10	Pollination	Role of biota in movement of floral gametes	10.1 Pollination of wild plant species. 10.2 Pollination of crops
11	Biological control	Population control through trophic-dynamic relations	11.1 Control of pests and diseases. 11.2 Reduction of herbivory (crop damage)
	Habitat Functions	*Providing habitat (suitable living space) for wild plant and animal species*	Maintenance of biological & genetic diversity (and thus the basis for most other functions)
12	Refugium function	Suitable living space for wild plants and animals	Maintenance of commercially harvested species
13	Nursery function	Suitable reproduction habitat	13.1 Hunting, gathering of fish, game, fruits, etc.
	Production Functions	*Provision of natural resources*	13.2 Small-scale subsistence farming & aquaculture
14	Food	Conversion of solar energy into edible plants and animals	14.1 Building & Manufacturing (e.g. lumber, skins). 14.2 Fuel and energy (e.g. fuel wood, organic matter). 14.3 Fodder and fertilizer (e.g. krill, leaves, litter).
15	Raw materials	Conversion of solar energy into biomass for human construction and other uses	15.1 Improve crop resistance to pathogens & pests. 15.2 Other applications (e.g. health care)
16	Genetic resources	Genetic material and evolution in wild plants and animals	16.1 Drugs and pharmaceuticals. 16.2 Chemical models & tools. 16.3 Test- and essay organisms
17	Medicinal resources	Variety in (bio)chemical substances in, and other medicinal uses of, natural biota	Resources for fashion, handicraft, jewelry, pets, worship, decoration & souvenirs (e.g. furs, feathers, ivory, orchids, butterflies, aquarium fish, shells, etc.)
18	Ornamental resources	Variety of biota in natural ecosystems with (potential) ornamental use	
	Information Functions	*Providing opportunities for cognitive development*	
19	Aesthetic information	Attractive landscape features	Enjoyment of scenery (scenic roads, housing, etc.)
20	Recreation	Variety in landscapes with (potential) recreational uses	Travel to natural ecosystems for eco-tourism, outdoor sports, etc.
21	Cultural and artistic information	Variety in natural features with cultural and artistic value	Use of nature as motive in books, film, painting, folklore, national symbols, architect., advertising, etc.
22	Spiritual and historic information	Variety in natural features with spiritual and historic value	Use of nature for religious or historic purposes (i.e. heritage value of natural ecosystems and features)
23	Science and education	Variety in nature with scientific and educational value	Use of natural systems for school excursions, etc. Use of nature for scientific research

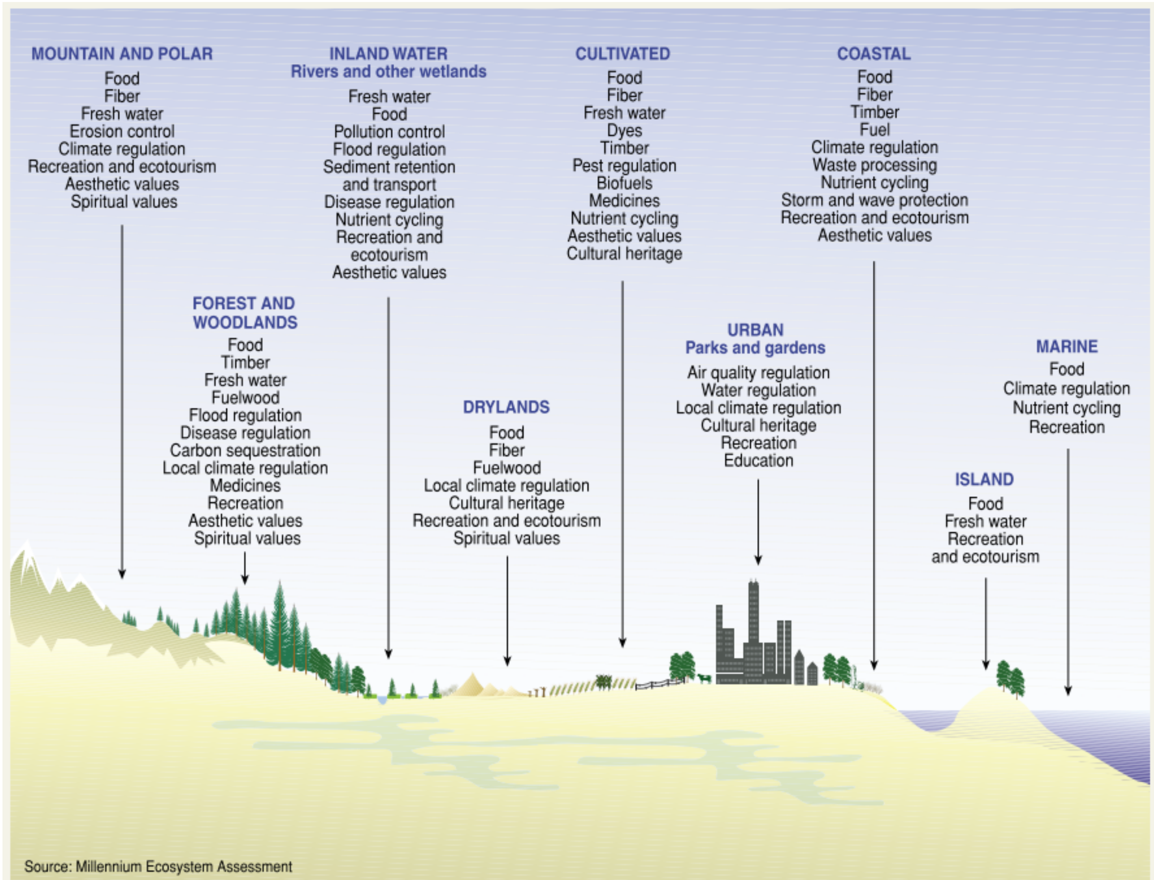

Figure 1: The combinations of services provided to humans from ecosystems, across a landscape.

Ecosystem services are delineated into provisioning services, regulating services and cultural services, (Gómez-Baggethun and Barton 2013, Schaefer et al. 2015, Percy et al. 2005, Steger et al. 2018, Tzoulas et al. 2007).

Regulating- Regulating services are the benefits obtained from natural processes, such as climate regulation, soil fertilization and water purification.

Provisioning - Provisioning services include resources that are necessary for human survival such as food, water, fuel, and medicine. They are tangible products of ecosystems able to be extracted and owned, and are thus easily standardized, commodified, and traded.

Cultural - Non-material benefits people obtain from ecosystems, such as inspiration, cultural identity, and recreation and considered cultural ecosystem services. These services arise from intimate relationships between people and their environments, and as such are difficult to approximate through economic substitutions (Raymond, Giusti, and Barthel 2018).

2.3 Valuing Ecosystem Services

The most common methods applied to ecosystem service valuation apply an economic framework. Although useful, the standardization and widespread adoption of economic methods for valuing ecosystem services has drawbacks, including the potential for scarcity due to speculation, and overshadowing intrinsic non-monetary values that are more difficult to quantify, (de Groot, Wilson, and Wilson 2002, Gómez-Baggethun and Barton 2013, Johnson 2015, Schaefer et al. 2015, Steger et al. 2018).

There is a clearly a public good created through the application of ecosystem services and it is common economic knowledge that many externalities created from public goods cannot be properly captured through pure economic valuation (Helbling 2012). Economic metric approaches do not easily capture regulating or cultural services which ecosystem services provides, only provisioning services. Most regulating services are 'public goods', which are "non-excludable and multiple users can simultaneously benefit from using them," (Costanza et al. 2017).

How to measure and evaluate ecosystem services depends on what the entity assigning the value deemed as important to be measured. We measure what has value to us. An argument is often made against placing a dollar value on ecosystem services due to moral reasons. But as explained by Constanza and his economic colleagues in one of the first efforts to measure ecosystem services, that argument is a translation of value in and of itself.

> "Moral arguments translate the valuation and decision problem into a different set of dimensions…one that makes the problem of valuation and choices more difficult and less explicit. The decisions we make as a society about ecosystems imply valuations….(w)e can choose to make these valuations explicit or not…but as long as we are forced to make choices, we are going through the process of valuation,"
>
> -"The value of the worlds ecosystem services and natural capital", published in Nature (1997, 387).

2.4 Frameworks for Measuring Ecosystem Services

By the 2010s a multitude of international and national organizations had developed their own metric frameworks, with the goal of enabling ecosystem services to be considered in policymaking and upholding regulation. Below is a non-exhaustive list of major valuation initiatives.

International Metric Efforts

- Millennium Ecosystem Assessment, (2001): Developed a broad conceptual framework linking ecosystem services and human well-being through socio-economic factors; be applied based on global ecosystem changes (MEA 2005).
- National Accounting Matrix including Environmental Accounts (NAMEA)- Applied in the European Union, a strategy on environmental data generation for policy support to assess sustainable production and consumption performance (UN 2005).
- Extended Environmental Input Output (EEIO): As described in Tukker et al. EEIO approach allows identifying the main sources of environmental problems within the economic system, thus providing information for impact assessment of environmental protection policies (2006). The outcomes of the assessments are meant to inform policymaking about trends in environmental performance related to the economy.
- The Economics of Ecosystems and Biodiversity (TEEB)- A meta-analysis that applies basic value-transfer method. Its principal objective is to mainstream the values of biodiversity and ecosystem services into decision-making at all levels (TEEB 2010).
- Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, (IPBES) (established 2012): Exists to strengthen the science-policy interface for biodiversity and ecosystem services for the conservation and sustainable use of biodiversity, long-term human well-being and sustainable development (IPBES 2019).

National Metric Efforts

- Federal Resource Management and Ecosystem Services (FRMES) guidebook developed for government agencies to assist natural resource managers in incorporating ecosystem services into planning and management processes (Olander 2016). The guidebook includes an accounting framework and assessment methods. The contributors to this guidebook are in a partnership including Duke University's Nicholas Institute for Environmental Policy Solutions.
- Final Ecosystem Goods and Services (FEGS) (2013) – Developed for the U.S. Environmental Protection Agency to provide a foundation for measuring, quantifying, mapping, modeling, and valuing ecosystem services (Landers and Nahlik 2013).
- Conservation Economy Framework (2002) – Created to understand and measure bioregional ecosystem services in the Northwestern United States (Ecotrust 2002).

The exchange of knowledge could grow substantially, if urban ecosystems services research could agree on a common set of ecological indices and metrics (Ahern, Cilliers, and Niemelä 2014, Nahlik et al. 2012). As more researchers have published information on ecosystem service valuation, most agree that valuing these services is a complex challenge that requires a multi-disciplinary approach.

2.5 Planning & Ecosystem Services

Stakeholder Engagement & Participation

Despite there being many organized bodies attempting to place a valuation system on ecosystem services, applying this valuation into planning continues to be elusive. In order for ecosystem services to be an effective tool in planning, an increase in the utilization of metrics and a better understanding of stakeholder values must combine to help prioritize which ecosystem services are most important to increase or maintain in a particular community (Costanza et al. 1997). There will inevitability be a give-and-take when making decisions on how to develop/redevelop land or the policies surrounding such issues. However, it is generally agreed upon that planning informed by an ecosystem service framework could help include important ecological information into decision-making processes (Ahern, Cilliers, and Niemelä 2014, Gómez-Baggethun and Barton 2013, Schaefer et al. 2015). If ecosystem services were assigned value based on multiple viewpoints, then equity and economic tradeoffs would inevitably be included in the give and take valuation (Ahern, Cilliers, and Niemelä 2014, BenDor et al. 2017). It would be remiss not to state the obvious: that this inclusion of environment, equity and economics reflects the triple-bottom line that is often referred to when sustainability applications are debated.

Berke and Godschalk analyzed comprehensive land use plans from 42 U.S. municipalities to identify factors that support sustainable development. They identified that planning which required the involvement of a broad number of groups or organizations in planning increased the plan's overall support for ecology concepts, including sustainable development (2009). Further, no pathway for ecosystem health, natural, urban, or global, that does not accommodate the values and needs of "real people" living in conventional communities will be sustainable, (Guidotti 2010). Thus, an ecosystem services framework in planning should intentionally incorporate the involvement (and hopefully values), of multiple stakeholders into the decision-making.

Contribution to Sustainability and Resiliency in Planning

The terms resiliency and sustainability are evermore present in planning discussions as global climate change and the era of Anthropocene have forced policymakers to think in broader terms about how to prepare for an uncertain future. Ecosystem services contribute to resiliency and sustainability because they are providing functions necessary for human and other systems' survival. Therefore, ecosystem services contribute to human sustainability and resiliency on this planet, but they are only a subset of the larger sustainability and resiliency planning agenda.

Holling's seminal article termed resilience of ecological systems as a measure of the persistence of systems and their ability to absorb change and disturbance and still maintain the same relationships between populations or state variables (1973). The concept of resiliency has become increasingly important to the planning practice as the influence of random events on ecosystems increase, exasperated by global climate change. One measure to assess ecosystem integrity is based on how it adapts and responds to external stresses (Guidotti 2010).

In the 2001 Annual Review of Ecology and Systematics, ecosystem services were described as one of the insurance factors contributing to resiliency of cities (Pickett et al.). Ecosystem services and green infrastructure are often strategies that contribute to the resilience of man-made structures, such as cities, (Shirgir, Kheyroddin, and Behzadfar 2019). Resiliency applies the foundational aspects of absorption, restoration, and adaptation (Tran et al. 2017). In section 2.6 below, it is explained that a healthy ecosystem is one that reflects these aspects of resiliency. For example, enabling ecosystem services within a place very likely increases biodiversity, (depending on the extent of ecosystem services implemented). Species-rich heterogeneous habitats are considered to be more resilient than homogeneous habitats (Tzoulas et al. 2007).

Sustainability is a vague term that requires a negotiated balance between economic, environmental and equity values applied to policy making and beyond. The Brundtland Report specifically called for sustainability to meet the needs of the present without compromising the ability of future (human) generations to survive (WCED 1987). After the Brundtland Report, the term sustainable development emerged as an overarching guide to planning aimed at sustainability (Berke 2002). Sustainable development requires more than an application of ecological or planning concepts. It entails reconciliation and synergy between environmental, economic, and social concerns and thus requires knowledge that is integrated across fields (Reynolds 2012).

As is the case in explaining the relationship of ecosystem services with resiliency, ecosystem services can be used as a tool to strive towards sustainability. But the application of sustainability concepts is not required for the application of ecosystem services. Ecosystem services could be implemented within a community or campus, but other applications of sustainability may not be present.

According to Constanza, ecosystem services can provide positive contributions to human wellbeing which are either never or only vaguely perceived or may only manifest themselves at a future time (Costanza et al. 2017). Therefore, if we are aiming to follow the Brundtland definition of sustainability, we cannot ignore something's value just because we do not completely understand the value at the present moment. We are sure that a functioning ecosystem is necessary to provide certain outcomes required for human life to exist on the plant: clean air, clean water, healthy soils to produce our food, etc. If valuing ecosystem services enables us to support the continuation of these outcomes, logic indicates we must act to protect said services.

2.6 Connecting Human Health and Ecological Performance

Green Infrastructure

The term green infrastructure is often referenced when planning documents or policies are addressing benefits provided to humans by ecological characteristics, functions or processes. As summarized by multiple published papers from the research community, human developments depend on ecosystems and their components to sustain long term conditions for life, health, security, good social relations and other important aspects of human well-being (Brussard, Reed, and Tracey 1998, Costanza et al. 1997, Costanza et al. 2017, Gómez-Baggethun and Barton 2013, Tzoulas et al. 2007). This human health-ecological performance relationship in planning is the crux of applying ecosystem services, so it is important to recognize alternative phrases which are closely related to ecosystem services.

Green infrastructure is a concept that has emerged as a way to secure ecosystem services in human-dominated landscapes (Colding 2011). Other terms related to ecosystem services that have been used, sometimes interchangeably, in planning and land use include:

Natural Capital, Low Impact Development, Ecological Landuse Planning. The later was probably most broadly discussed at first in McHarg's Design with Nature (1969).

Green infrastructure is meant to contrast the term grey infrastructure, which would be traditional pipes, asphalt and the like that humans have used to build traditional infrastructure in the past. Green infrastructure is generally defined as an interconnected network of natural areas supported with semi-natural and artificial infrastructures that provide natural ecosystem values and functions, sustains clean air and water, and provide a wide array of benefits to people and wildlife (Ahern, Cilliers, and Niemelä 2014, Benedict and McMahon 2006, Schaefer et al. 2015, Tzoulas et al. 2007). The part of the definition which authors differ on is how the infrastructure is connected, (naturally, artificially or hybrid). What is not argued is that a network across spatial scales must be present to truly fit within the category of green infrastructure.

A causal relationship between green infrastructure and human health has not been established, but many previous studies and literature reviews have focused on associations (Kent and Thompson 2014). The paper "Promoting ecosystem and human health in urban areas using green infrastructure: A literature review" developed a conceptual framework integrating green infrastructure, ecosystem health and human health. This framework identified six areas of ecosystem health: air quality; soil structure; energy and material cycling; water quality; habitat and species diversity; ecosystem resilience (Tzoulas et al. 2007).

Tzoulas claimed that the direct link between ecosystem health and public health is the set of ecosystem services provided by the green infrastructure (2007). To illustrate this link, Tzoulas et al. conducted a comprehensive review of studies that explored the contributions of green spaces and nature to human health. See table 2, “Model and theories linking ecosystem and human health aspects”.

Table 2: Model and theories linking ecosystem and human health aspects (Tzoulas et al. 2007).

Models and theories linking ecosystem and human health aspects

Author	Model/theory	Green Infrastructure aspect	Human health aspect
Freeman (1984)	Model of Environmental Effects on Mental and Physical Health	Physical, social and cultural factors	Nervous system and manifested illness
Henwood (2002)	Psychosocial Stress and Health Model	Poor environment	Chronic anxiety, chronic stress and high blood pressure
Pickett et al. (1997, 2001), Grimm et al. (2000)	Human Ecosystem Framework	Ecosystem structure and processes and cultural and socio-economic resources	Socio-ecological systems
WHO (1998)	Arch of Health	Environmental, cultural, socio-economic	Working and living conditions, community, lifestyle and hereditary factors
Paton et al. (2005)	Healthy Living and Working Model	Environmental, cultural, socio-economic	Living and working conditions
Millennium Assessment (2003)	Links between ecosystem services and human well-being	Provisioning, ecosystem services, regulating and cultural	Security, basic resources, health, social relationships, and freedom of choice
Macintyre et al. (2002)	Framework based on basic human needs	Air, water, food, infectious diseases, waste disposal, pollution	Human needs (biological, personal, social, and spiritual)
van Kamp et al. (2003)	Domains of liveability and quality of life	Natural environment, natural resources, landscapes, flora and fauna, green areas	Health all aspects (physical, psychological, social)

Tzoulas is not alone in his efforts to illustrate the relationship. According to the Millennium Ecosystem Assessment, there is a close relationship between ecosystem health and ecosystem services. As explained:

> “Increasing ecological stress leading to a reduction in both the quality and quantity of ecological services. In contrast, healthy ecosystems have the capacity to provide a comprehensive range of ecosystem services. Therefore, ecological functions and ecosystem services derived from a green infrastructure contribute to ecosystem health and to public health, respectively,” (MEA 2005).

Ecological Health

A healthy ecosystem is one that is free from distress and degradation, maintains its organization and autonomy over time and is resilient to stress (Costanza et al. 1997). Ecosystem health is dependent on a mixture of different processes working together synergistically. Six areas of ecosystem health are generally accepted: air quality; soil structure; energy and material cycling; water quality; habitat and species diversity; ecosystem resilience (Lu and Li 2002). However the concept of ecosystem health is not unanimously accepted (Bayles et al. 2016, Lu and Li 2002, Su, Fath, and Yang 2010, Tzoulas et al. 2007).

Some environmental performance could be gained even if the local ecosystem may not be considered healthy. For example, a rain garden placed alongside a block of commercial buildings on an urban street provides some water filtering, (regulating services), a stormwater management function, (provisioning services), pollination, (provisioning services) and pleasant greenspace for humans to enjoy, (cultural services). However, this rain garden and its ecological connection overall may not be performing as an optimum, balanced system that supports biodiversity and nutrient cycling. Nonetheless, the raingarden is providing some level of benefit to humans and therefore environmental performance is happening.

Human Health

The World Health Organization defines human health as “a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity” (WHO 1948). In 2013, the American Public Health Association issued a policy statement on ‘‘Improving Health and Wellness through Access to Nature’’ that calls for joint action by professionals in public health, parks, recreation, and urban planning and design (Chawla 2015). The presence of green, natural settings is important in facilitating good mental health and community connection, as well as promoting physical activity. This is supported by a raft of research studies summarized by Kent and Thompson (2014).

To illustrate: where there are ecosystem services, there is likely more greenspace, or green infrastructure providing a resource for natural systems. If ecosystem services are planned alongside alternative transportation options such as walking and bicycle paths these services do dual duty for ecological health and social health and well-being. The availability of ecosystem services fundamental to the wellbeing of a population. Hence, the inclusion of ecosystem services in planning is essential to promote sustainable development (Cortinovis and Geneletti 2018).

A primary message repeated in the literature discussing human health and ecological performance is that the relationship between people’s health and the built environment is complex and contextual (Bayles et al. 2016, Chawla 2015, Lu and Li 2002).

2.8 Higher Education and Ecosystem Services

Universities and other higher education settings hold a unique position in society in that they train and educate people, (some) perform significant research and they participate in policymaking at the national and regional level. Because of these reasons, higher education institutions represent pivotal settings for practical change in navigation towards a more sustainable future (Colding and Barthel 2017).

There are several notable organizations working to integrate sustainability into higher education. The below effort to list these organizations was focused on which include an element of ecological imperative in their approach.

- The Association for the Advancement of Sustainability in Higher Education's (AASHE): AASHE's Sustainability Tracking Assessment and Rating System (STARS) was first piloted in 2008, (2019). This self-reporting framework allows an institution to earn points toward a STARS rating; it is currently pursued by a total of 999 higher education institutions. The 2.1 framework recognizes institutions' efforts towards conserving endangered species and ecologically sensitive areas and, more generally, engagement in ecologically sustainable grounds management. But these ecological considerations are only two of over sixty topics that encompass sustainability on the campus (AASHE 2019).
- International Sustainable Campus Network (ISCN): The mission of the ISCN is to provide an international forum to support higher education institutions in the exchange of information, ideas, and best practices for achieving sustainable campus operations and integrating sustainability in research and teaching (ISCN 2019). International organization consisting of 94 higher education members.
- The Association of University Leaders for a Sustainable Future (ULSF) is the Secretariat for signatories of the Talloires Declaration (1990), which has been signed by over 500 college and university presidents and chancellors worldwide. This organization focuses much of their recent efforts on bringing institutes of higher education together around the UN Sustainable Development Goals (ULSF 2015).

- Higher Education Sustainability Initiative (HESI) – This is partnership between United Nations Department of Economic and Social Affairs, UNESCO and many other international organizations. Provides higher education institutions with a unique interface between higher education, science, and policy making (UN 2019).

The potential for integrating higher education campuses in a global sustainability agenda is high. However, affecting meaningful outcomes at the campus level appears to be minimal, according to the literature. Most higher education institutions, despite environmental proclamations and commitments, approached sustainability in an ad-hoc way, often focusing on a limited number of environmental parameters (Alshuwaikhat and Abubakar 2008).

There have only been a handful of studies on sustainability planning in higher education, and the majority are specific case studies rather than multi-institution reviews (Alshuwaikhat and Abubakar 2008, McDuffie et al. 2015, Orenstein Daniel et al. 2019, Ryan 2018, Swearingen White 2014). Three studies do attempt to analyze a broader number of higher education institutes for their application of sustainability in planning. One conducted by White (2014), one by Orenstein (2019) and one by Velazquez and colleagues (2006).

Velazquez and colleagues surveyed nearly eighty universities globally in 2005. From the survey they developed a model for what a sustainable university should be.

> "A higher educational institution, as a whole or as a part, that addresses, involves and promotes, on a regional or global level, the minimization of negative environmental, economic, societal and health effects generated in the use of their

> resources in order to fulfill its functions of teaching, research, outreach and partnership and stewardship in ways to help society make the transition to sustainable life-styles" (Velazquez et al. 2006, 812).

According to this definition, the application of ecosystem services would support higher education institutions seeking to be sustainable.

Orenstein, et al, reviewed twenty-three universities to prepare to include ecological considerations into campus strategic and spatial planning at the Israel Institute of Technology. In their study, they benchmarked the best practices used by different universities that were active in implementing sustainability (Orenstein Daniel et al. 2019).

White analyzed twenty-seven campus sustainability plans from a broad cross section of community colleges, public and private colleges and universities across the U.S. White's analysis identified that:

> "Very few plans, (15 percent) had fully integrated goals, objectives and strategies…That (lack of) integration with other plans suggests some campuses may be struggling with ways to ensure sustainability concerns are embraced throughout an institution's other planning efforts" (Swearingen White 2014, 234).

2.9 Campuses as Mini-Cities

There has been much written on why colleges and universities should be embracing ecosystem services, not just in planning, but also in academic and research applications. A primary argument for increasing ecosystem services into campus applications is that many higher education campuses are operating as an integrated community, or even a mini-city

(Ahern, Cilliers, and Niemelä 2014, Colding and Barthel 2017). From the decision-making hierarchy, to operational practices to influencing stakeholders, the campus is a perfect petri dish for applying concepts of sustainable development. As a city in microcosm a university campus is able to test new ideas and these ideas can then be scaled to other settings" (Swearingen White 2014). This is the living-learning-laboratory concept.

One study, "The concept of ecosystem services in adaptive urban planning and design", proposed an adaptive urban design framework meant to enable ecosystem services to be implemented more broadly in cities (Ahern, Cilliers, and Niemelä 2014). The premise of the study was that adaptive applications of ecosystem services combined with standardized information collection and sharing would enable quicker up-take of these services across municipalities. According to Ahern and colleagues, this "safe-to-fail" framework can provide a structure to integrate science, professional practice and stakeholder participation (Ahern, Cilliers, and Niemelä 2014). If campuses really do act as mini cities, then the application of this framework should be transferable to campuses.

Campuses as "cities in microcosm" suggests that lessons from the development and implementation of these plans will be very useful to sustainability efforts in other settings and at other scales (Swearingen White 2014, 238). Further the idea that many U.S. college campuses are acting as mini-cities also illustrates why campus planning documents should be developed like local plans, entailing a long-term vision as well as specific implementation inclusions, (Rudolf and Gradinaru 2019). This concept is discussed further in this document under the "General Plan Evaluation" section.

2.9 General Plan Evaluations

When comparing higher education planning documents against other types of plans, the higher education documents most closely parallel local plans – also known as ‘‘comprehensive’’, ‘‘general’’, ‘‘master’’, and ‘‘community’’ plans in the literature. Like local plans, these higher education plans aim to provide a vision to steer the long-term development of municipalities, (or campuses) and define policies to steer local development towards achieving this vision (Rudolf and Gradinaru 2019).

In the last thirty years, several comprehensive studies have been conducted in an attempt to identify what makes a good plan (Baer 1997, Cortinovis and Geneletti 2018, de Groot et al. 2010, Gómez-Baggethun and Barton 2013, Rudolf and Gradinaru 2019). Historically, there have been three main dimensions of plan evaluation: fact based, goals and tactics or policies (Berke 2002). Then in 1999 Godschalk et al. added implementation and evaluation dimensions (Rudolf and Gradinaru 2019).

The academic community has been encouraging more detail and analysis regarding plan implementation. Rudolf and Gradinaru developed a framework to assess the relationship between plan quality and plan implementation (2019). Their method relates communication and action-oriented outcomes with performance. This implementation interest across the research is in line with the purpose of this study, which aims to understand how ecosystem services are being applied to planning and whether metrics are included in higher education plans.

CHAPTER 3. LEARNINGS & IMPLICATIONS

Through the literature review this paper has aimed to illustrate the current state of applying ecosystem services to planning, as well as to better understand that higher education institutions are and are not actually doing regarding ecosystem services and planning. The analysis that follows will take a deeper look into how a sample of R1 universities in the United States are applying ecosystem services in planning efforts.

There is much we do not know about how to apply ecosystem services to planning. There is a long history of planning efforts from various disciplines recognizing the benefits of functioning ecosystems, but there are not many analyses of plans using an ecosystem services framework (Wilkinson et al. 2013). Professionals from the fields of economics, planning, landscape design, public policy and public health have been grappling the actual methods of application since McHarg. The last twenty-five years or so has shown an up-surge in attempts to measure ecosystem services and apply those metrics to policy making.

What we do know is that including ecosystem services in planning requires a more intense level of valuation, beyond economics. It is also emerging that measuring the outcomes of plans is a best practice (Costanza et al. 1997, Rudolf and Gradinaru 2019). Identifying and applying metrics to ecosystem services in higher education planning could help support this best practice.

3.1 Higher Education Campuses: Incubator for Cultural Ecosystem Services

The category of cultural ecosystem services is nebulous and often hard to associate direct value to (Colding and Barthel 2017, Raymond, Giusti, and Barthel 2018, Riechers, Barkmann, and Tscharntke 2018, Wartmann and Purves 2018). However there is evidence showing that natural areas can enhance students' authentic learning opportunities of biodiversity and increase feelings of nostalgia (Colding and Barthel 2017).

More than one study has investigated the various benefits obtained by individuals who visited forested areas, showing that cultural services were the main reason for visiting and (some identified) that mental health benefits were obtained, post visit (Riechers, Barkmann, and Tscharntke 2018, Torkar and Krašovec 2019, Wartmann and Purves 2018). By embracing the cultural aspects of ecosystem services campuses of higher education can contribute greatly to the valuing of cultural ecosystem services and even further, towards the transition to sustainable development practices.

If it is true that institutes of higher education can nurture and empower sustainability innovations to develop enough to get a foothold and successfully compete in a broader marketplace, (Colding and Barthel 2017), then some of this nurturing can begin with the intrinsic valuation of ecosystem services.

3.2 Change Agents for Sustainable Development & Resiliency

In the literature review, it was emphasized that sustainability concepts, including sustainable development, are not prerequisites for applying ecosystem services. However, ecosystem services are an important ingredient to enabling sustainable development and resiliency. If more colleges and universities could successfully apply ecosystem services to their planning efforts, these schools could be change agents in the transition towards sustainable development (Colding and Barthel 2017). There are potential benefits to be had at the local, regional and international scale if such application were pursued.

University campuses occupy a significant amount of land in multiple ecosystem types. The sheer spatial size of campuses and their populations indicates that their physical planning can have a profound impact on ecological characteristics of their region (Orenstein Daniel et al. 2019). Also, higher education campuses are not always strictly bound by municipal politics or traditional profit-loss decision making models. Therefore, testing new applications of ecosystem services should be easier to implement.

University campuses are tied to the urban and suburban communities in which they are situated, and they can have a profound impact on those local communities. This connection is only growing stronger as state funding of higher education is decreasing and dependency on research funding and public-private-partnerships is growing. As such, the opportunity for the exchange of information and best practices between local municipal governments, the private sector and institutions of higher education is ripe.

CHAPTER 4. METHOD

4.1 Search Approach for Literature Review

The question this study aims to answer is "Are ecosystem services being utilized within campus planning frameworks to address human health and environmental performance?" and then –"If yes- is there an effective measurement plan associated with said services to measure success?" To answer this question, an extensive literature review was conducted to understand the current state of ecosystem services in planning in general, and planning in higher education. Next a plan evaluation index was developed and applied to a sample of higher education planning documents.

The original intention of the literature review was to understand and summarize the themes and findings of works in the area of ecosystem services in planning, and then identify implications for the development of the plan evaluation. However, as the scale of the initiative came into focus, the literature review became a qualitative research initiative in and of itself. Significant effort was required to gain a clear understanding of the current state of ecosystem services in planning in general and in higher education specifically. However, without having this breadth of understanding, it would not be possible to effectively assess higher education plans, or to identify practical recommendations.

The reasoning for applying ecosystem services is most often to support sustainable development. The topic of sustainability is inherently interdisciplinary, and quite often transdisciplinary. Therefore, multiple fields of study needed to be explored. Between the initial investigation of ecosystem service definitions, planning approaches and associated metrics, the following research fields were explored during the literature review: ecology, clean production, environmental planning, semantics, urban planning, land use and land planning, city/urban sciences and systems engineering.

Next, a discovery was made of which associated journals would be covering such varied content. In addition to multiple websites and books, the final documents referenced spanned across twenty journals, with *Landscape & Urban Planning, Ecosystem Services* and *Ecological Economics* being the journals whose articles were most frequently cited. Those journal article entries were closely followed by multiple articles from *Journal of Planning Literature, Journal of Cleaner Production, International Journal of Sustainability in Higher Education* and *Sustainability*.

Search Combinations Applied:

1. Ecosystem services & environmental well being
2. Ecosystem services & human well being
3. Ecosystem services & health
4. Ecosystem services & ecological health
5. Ecosystem services & planning
6. Ecosystem services & higher education

Finally, the key findings were grouped by trends on what was important to applying ecosystem services to planning. From these groupings emerged the categories and attributes applied to the evaluative index. This information is culminated above in chapter two.

4.2 University Criteria for Evaluation

The initial criteria for identifying sample group of university plans was based on the terms of the literature review. Throughout the literature review, if a specific university was mentioned as a case study or to illustrate best practices in applying ecosystem services, the name of the institute would be added to a tracking list.

One search uncovered many potential higher education institutions for analysis. When conducting secondary research on planning for sustainability in higher education, the International Sustainable Campus Network (ISCN) was identified. On the ISCN's website was a "Sustainable Campuses Best Practices" downloadable document. The document included 42 case studies featuring best practices of sustainable universities (ISCN 2018). Every U.S. college or university with a featured case study even vaguely related to ecosystem services was added to the target list.

In order to promote some overarching congruencies in the research, it was important that the analysis compare institutions with basic similarities. Being bound by some of the same policies and organizational structure was a reasonable approach. Therefore, two additional restrictions were applied to the overarching list: include only institutions within the boundaries of the United States and then only institutions that were classified as R1 by the Carnegie Classification.

This R1 designation sets the following criteria, according to the Carnegie Classification: "Doctorate-granting Universities are institutions that awarded at least 80 research/scholarly doctorates in 2013-2014" (2018).

The university list was then reduced further by assessing each U.S. university to confirm if planning documents were readily available on the internet. MIT was ultimately excluded from the evaluation because planning documents were not available on the university websites.

4.3 Types and Numbers of Plans Included

Eight higher education institutions' planning documents were reviewed encompassing a total of twenty-two different plans, strategic initiatives or operational and landscape guides. This process included reviewing master plans, landscape master plans, stormwater master plans, environmental and green design plans and guidelines, sector plans, and sustainability plans. Special purpose sustainability plans were not included in the evaluation unless they were associated with or referenced in the campus master plan document.

Not every university had the same types of plans available for evaluation. See Table 3, "Complete List of Plans Evaluated, By University" for a full list of plans evaluated by university. The following analysis was based on published plans, listed on the associated university's website.

Table 3: Complete List of Plans Evaluated, By University

1. Georgia Institute of Technology	**2. Duke University**	**3. Indiana University-Bloomington**	**4. Yale**
Master Plan (2004), Landscape Master Plan (2010), Operational Tree Plans, Stormwater Masterplan (2013)	A Campus Master Plan, Updated MP Principles (2012), Landscape Character and Design Guidelines (2012), Sust. Guidelines, and Strategic Initiatives for Facilities (2008)	Master Plan (2010), Energy Master Plan(2012), Sub District Master Plan (2018)	Yale Sustainability Plan 2025 (published 2017), MP Framework Update (2009), Campus Planning Framework (2000)
5. Purdue	**6. UC Boulder**	**7. UC Berkeley**	**8. U. Mass-Amherst**
Master Plan (2018), Stormwater Master Plan (2009), Sustainability Strategic Plan (2010)	Master Plan Boulder (2011)	Framework for Capital Investment-(2003); Landscape Master Plan (2004), Long Range Devlp't Plan (2005)	Masterplan (2012), Sustainability Update (2015)

4.4 Plan Evaluation

Limitations

This research only evaluated planning documents from U.S. colleges and universities in an effort to frame the findings towards a domestic audience. Also, the evaluation only included planning documents that could be found posted within each institution's websites. This study reviewed campus sustainability plans if they were first referenced by master plans. The reasoning for this approach was that land use is fundamentally a part of ecosystem services. Master plans or other physical space plans almost always include land use guidelines. If one were to build upon this research a broader sample size and more comprehensive surveying of all available planning documents, including strategic plans and stand-alone sustainability plans would be recommended.

By not applying an empirical approach, there is an air of subjectivity. There are certainly shortcomings to a basic comparative approach. Applying an index approach was an attempt to reduce the potential for a subjective weighting of findings.

Also, a strong planning framework that includes or applies ecosystem services should utilize a participatory process is setting the values and valuation of those services. However, in evaluating the below plans, some which had been created up to 15 years prior, it was not possible to assess the level of participation of stakeholders included in the development. Therefore, stakeholder engagement was excluded from the evaluation. If a deeper analysis is conducted in the future, it would be useful to identify who was involved in the development of the plans, especially during the values and goal setting process. Perhaps first-person interviews could be applied to accurately assess the level of stakeholder participation.

Why an index?

An index was a way to create a composite measure that summarized what was included in the plans, according to three categories. An index is an efficient way to reasonably measure and rank a set of similar objects or groups of objects. The index created for investigating the research question equally weighted each category of ecosystem services in plans. (Read more about these categories in the next chapter, "About the Index".) The reasoning for equal weighting was that each section is very important to furthering ecosystem services within planning in higher education. All three of the main areas were identified as important in the literature. Therefore, it would not be useful to promote or demote one area more than another.

All three of the main categories are regarded as important in the literature. Therefore, an equal index that averages scoring outcomes of these three categories avoids the promotion or demotions of one area more than another. Further, each of the attributes identified within the categories surfaced as important to fully recognizing the utilization and application of ecosystem services in planning. While this index approach is not a comprehensive assessment, it aims to capture the majority of important categories associated with utilizing ecosystem services in higher education planning. Defining three overall areas of ecosystem services in planning ensures that there is balanced recognition of efforts.

Lastly, indices are simple to interpret. Given that the interpretation of the plans' content was subjective, and that many of these plans spanned well over 150 pages in content, simplifying final rankings enabled outcomes that could be easily understood and communicated. It is a goal of this research that professionals working in planning for higher education can apply some of the learnings to their own campuses. To that end, simplification of results is important.

CHAPTER 5. ABOUT THE INDEX

Three subject areas were identified which reflect what the literature says the "ideal" should be as it relates to applying ecosystem services to planning: general concepts of ecosystem services, depth of application and implementation & effectiveness. These three subjects were then broken into eleven different attributes, further defining portions of the categories. The final index score is an average of the three category scores. Including these three areas as "separate but equal" is done by averaging the final score. The average is meant to enable a balanced recognition of efforts. The index developed for this study is specifically meant to assess plans based on the inclusion of and then quality of application for ecosystem services. It is not meant to be a comprehensive evaluation of the planning documents. To review a detailed explanation of how the index was applied to each planning document, see Appendix A: Scoring Guideline Sheet.

5.1 General Concepts of Ecosystem Services

This category aims to score the clarity with which the plans articulate any importance of ecosystem services. Points are awarded depending on how specific the documents describe services provided by nature. If services are directly mentioned, that attribute receives a full point score, but if services are mentioned as needing to be added to or continued on the campus, but no direct mention of human health or environmental performance is included, the attribute score drops by half. According to Berke and Godschalk in their meta-analysis "Searching for the good plan", when issues are clearly articulated early in the plan document, then subsequent plan elements are more apt to squarely address those issues (2009).

Whether the ecosystem services are attributed to impacting human health or environmental performance are each scored as separate attributes in this category. This results in three scorable attributes in this category.

5.2 Depth of Application

This section is aimed to analyze of the quality of the information included in the plans. Do the plans go beyond including singular ecological processes and is spatial connectivity and scale considered? If so, the literature indicates that the ecosystem services should be more effective through the provision of synergistic services, as discussed above. There are inherent linkages in an ecosystem that are difficult to decouple, and which work better as a whole rather than in parts (Leach 2019).

Sample of Analysis

A plan that includes a requirement for wetland delineation may only identify the benefit of wetlands as a flood buffer. But the planning documents go on to discuss the wetland quality or synergistic benefits derived from healthy wetlands, (such as the water quality/filtering, the creation of storm buffers, and estuary). In the case of scoring this plan, the attribute "Overall or Singular" would receive two times the points, resulting in an attribute score of 50 points. If the planning documents stopped referencing the value of wetlands beyond a flood buffer, the attribute would receive a single application of points, resulting in a category score of 25 points.

Spatial Connectivity & Scale

As reviewed above in section 2.6 Connecting Human Health & Ecological Performance, substantial research efforts have identified that promoting landscape ecology concepts, such as spatial connectivity, multi-functionality, and scale, is integral to maximizing what ecosystem services can be delivered in urban landscapes (Brussard, Reed, and Tracey 1998, Costanza et al. 1997, Costanza et al. 2017, Gómez-Baggethun and Barton 2013, Tzoulas et al. 2007). Simply put: the whole is worth more than the sum of its parts.

Local or Regional Considerations

The geographic scale of services is an important variable to consider. For this criterion, plans were evaluated to assess whether the benefits of the ecosystem services were considered in light of local or regional priorities. Defining and measuring ecosystem services at the local level has significant implications for both the quantity and quality of data used in the planning process. As noted by Colding and Barthel, the sheer spatial size of campuses and their population means that their physical planning can have a profound impact on ecological characteristics of their region (2017). It is often recognized that achieving societal change is best pursued at the level of groups and local communities (Colding and Barthel 2017).

5.3 Implementation & Effectiveness

Implementation and effectiveness were developed as a dedicated category in the index because it is not enough to simply write down what is hoped for. Useful planning must address the actions required to enable the plan into successful existence. This category of the index was specifically asking: Do the plans translate into action or contribute to a valuing of ecosystem services? Whether metrics were included was vital to understanding a plan's quality. Ultimately, if humans are to adopt the broad application of ecosystem services intrinsic specific valuation methods will be important to the uptake. This category includes the kinds of factors that are more likely than not to be useful in the future expansion of ecosystem services. As explained by Berke and Godschalk, good plans should present information and offer policy solutions in ways that make them useful and relevant in promoting awareness and support of the public interest of the community (2009).

Communication & Engagement

Communication and engagement was an attribute included in the index because information about ecosystem services must be visualized and communicated during the planning process and after, once the plan is being implemented (BenDor et al. 2017). Further, as discussed under "Campuses as Mini-Cities" section above, higher education campuses are uniquely positioned to test and nurture new methods of sustainable development. Therefore, ranking the institute's effort in this area was important.

CHAPTER 6. PLAN EVALUATION & FINDINGS

The overall index scores, as well as highlights from each of the three index categories are included below. To review the detailed scoring sheets for each university, see “Index Score Sheets - Details” Appendix C.

6.1 Index Scores

Mean scores on a scale of 0 to 100 are presented in the Average Index Scores table below. The highest overall average was a 92.2, earned by Indiana University-Bloomington. The lowest overall average was 57.2 earned by Duke University.

Table 4: Index Scores - Summary

SCHOOL	GENERAL ES	DEPTH	EFFECTIVENESS. & IMPLEMENT.	OVERALL SCORE (Averaged)
Georgia Institute of Tech.	100	100	47	82
Duke	50	75	47	57
Indiana Univ.-Bloomington	100	100	77	92
Yale	100	75	83	86
Purdue	75	50	53	59
Univ. Colorado - Boulder	75	25	83	61
Univ. Calif.-Berkeley	75	50	67	64
Univ. Mass- Amherst	75	100	27	67

Table 5: Average Scores Per Category

	GENERAL ES	DEPTH	EFFECT. & IMPLEMENT.	OVERALL AVERAGE SCORE
AVERAGE SCORE PER CATEGORY	81	72	60	71

Category Scores: General Ecosystem Services

Every institute whose planning documents were evaluated recognized ecosystem services either directly or indirectly. Three of the eight institutions (38%) earned the full score available in the general ecosystem services category. This full point score indicates that the planning documents specifically discussed services that nature provides and how these services benefit humans. Also, the plans directly recognized that human health and environmental performance were outcomes related to planning for ecosystem services on their campuses.

Two of the universities (UC Berkeley and UC Colorado) reviewed are valuing “sense of place” as a cultural service in their planning documents. Their plans place a higher emphasis on land use decisions, particularly related to conservation and open space.

The most recognized ecosystem service was using naturalized systems or green infrastructure for stormwater management. Seven out of the eight sets of planning documents, (88%) recognized the value of these elements and recommended they be applied.

The lowest scoring institute in this category was Duke University. Duke recognized that there was some benefit to the ecological performance in their Sustainable Design Framework with the inclusion that to "preserve and strengthen Duke's Identity as a University in the forest (would) improve occupant experience," (2014). However, no other mention of ecosystem services was included in the three planning documents available for review.

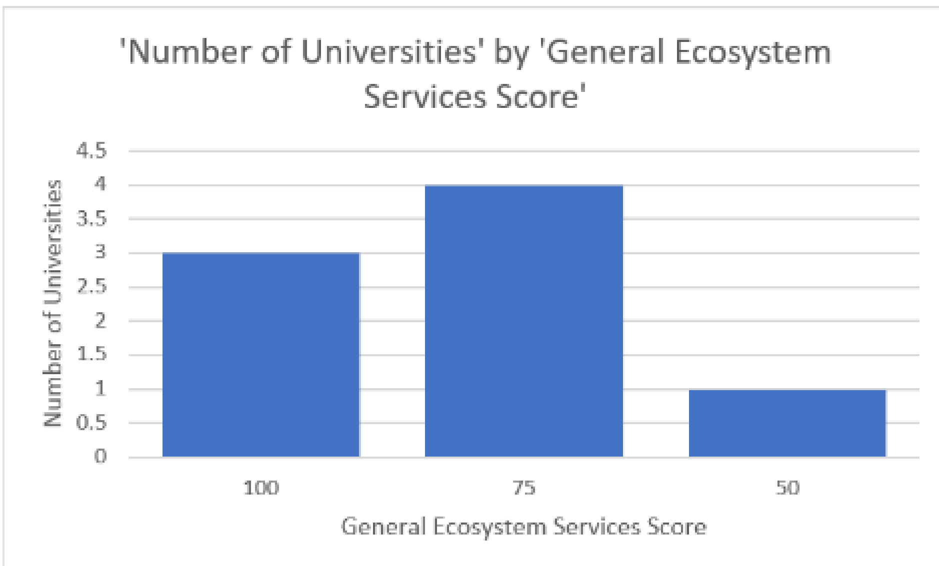

Figure 2: General Ecosystem Services Category Scores

Category Scores: Depth of Application

When it came to recognizing or aiming to realize the benefits of applying ecosystem services at a system level, the higher education institutions reviewed were equally split. Exactly half of the institutions analyzed only recognized ecosystem services in a singular application and half recognized ecosystem services as providing synergistic benefits. There were three ways that universities could earn points in recognizing a depth of services: the synergistic performance of overall the ecological system; identifying or recommending scales and connectivity opportunities; including or attempting to address local or regional ecological imperatives or implications with the planning documents.

To illustrate: UC Berkeley's master plan discussed the benefit of using bioswales for stormwater management, (2004), while Indiana University-Bloomington documents referenced that restoring a river running through campus would provide: a focal point of sustainably managed resources; an important habitat connection and stormwater management benefits. In Indiana University-Bloomington's planning documents, (2010), there was a clear recognition of the synergistic benefits that arise when an ecological system is intact.

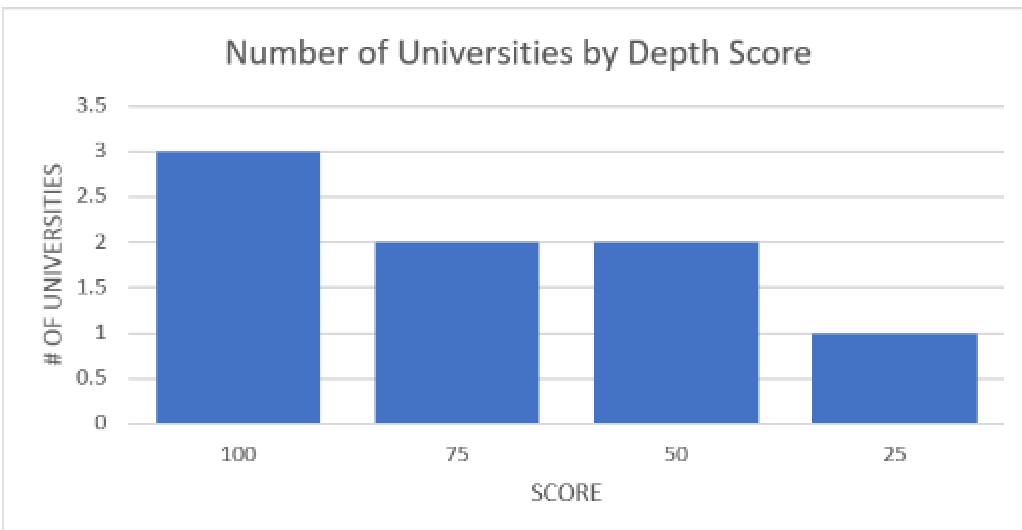

Figure 3: Depth of Ecosystem Services Category Scores

Category Scores: Effectiveness & Implementation

This sample set of planning document resulted in very low scores when reviewed for the application of ecosystem services. The low scores in the Effectiveness & Implementation category illustrate that, despite strong recognition of ecosystem services as a planning tool, the connection to actual implementation is lacking. This indicates that while planning documents recognize the importance of ecosystem services, they are not widely including:

- Methods for measuring ecosystem services, (economic or otherwise)
- Recommendations for how to engage stakeholders in the benefits provided by ecosystem services
- Implementation guidance or coordination

This outcome is not surprising, though it is unfortunate when the target locations are college campuses. The literature on general plan evaluation (section 2.9 above) indicates that providing implementation guidance or requiring metrics is a fairly new recommendation. However, the concept of measuring ecological performance is not new to the landscape architecture and civil land planning industries. This is probably why the most mentioned metric in the plans analyzed was that of stormwater management/runoff. Impact fees related to stormwater management have been in place in metropolitan areas for years, therefore measurement methods are well established.

The two institutes with the highest scores in the Effectiveness & Implementation category were University Colorado (UC) Boulder and Yale. UC Boulder's Master Plan stood out in the analysis of this category because the overall master plan was very broad but also very prescriptive. In order to assure metrics are applied to the goals, the plan references third party certifying bodies STARS and LEED (green building), metrics to strive towards. The plan also identifies very specific implementation tools and methods.

Yale's Sustainability Plan was the most recently published of all of their planning documents. In the document it specifically states that Yale will "plan and preserve resilient and sustainable infrastructure and landscapes" (2017). Then very specific tactics are targeted to support the operation of said infrastructure and landscapes. These include the following targets:

- Landscape management standards = complete, 2020
- Tree management plan = complete, 2019
- Green space use strategy launched, aiming for 2021

Figure 4: Effectiveness & Implementation Category Scores

6.2 Post Comparison: Participation in Formal Higher Ed Sustainability Organizations

A tertiary review inquired on participation in national or international organizations that encourage sustainability best practices. The question was whether participation corresponded to an increase of the ecosystem service index scores. If so, participation in such organizations or efforts may have encouraged the inclusion of ecosystem services into planning. Below are the general findings. However, the sample size is too small to identify any correlation. Observations of interest included:

- The two universities with the lowest index score for applying ecosystem services in their planning (Duke and Purdue), were also two of the three universities that had not updated their STARS reporting in the previous three years. AASHE STARS considers a report that is more than three years old to be expired (AASHE 2019).
- Two of the universities identified for this analysis were found in the International Sustainable Campuses Best Practices booklet: Yale and UC Berkeley. Only Yale is a member of ISCN.
- Only two of the higher education institutions analyzed were members of any of the three most noted international organizations supporting sustainability in higher education (Yale and UC Boulder).

Table 6: International Sustainability Orgs and STARs Reporting

Institute	Member of Network? (Y/N), #	International Sustainable Campus Network (ISCN): (Y/N)	AASHE STARS: Y/N, last year reported	Higher Education Sustainability Initiative (HESI): (Y/N)	University Leaders for a Sustainable Future -Tailloires: (Y/N)
Duke University	Y, 1	N	Y, 2015	N	N
Yale University	Y, 2	Y	Y, 2018	N	N
Georgia Institute of Technology	Y, 1	N	Y, 2012	N*	N
University of California, Berkeley	Y, 1	N	Y, 2018	N	N
University of Massachusetts Amherst	Y, 1	N	Y, 2018	N	N
Indiana University, Bloomington	Y, 1	N	Y, 2018	N	N
Purdue University, West Lafayette	Y, 1	N	Y, 2013	N	N
University of Colorado Boulder	Y, 2	N	Y, 2018	N	Y

CHAPTER 7. CONCLUSIONS & RECCOMMENDATIONS

There is a lost opportunity that exists on higher education campuses. The literature says that including ecosystem services in planning is important. According to this analysis, certain R1 campuses are broadly including ecosystem services in their planning efforts, but they have not yet mastered the implementation or measuring of these services. There are particularly weak points in planning documents as it relates to considering broad, synergistic ecosystem services, recognizing the value of cultural ecosystem services, and including effective measures and implementation strategies.

Aside from large innovative corporate campuses such as Google and Apple, higher education is one of the only places that is built and operated like a small city. Theories of sustainable development are being taught to students, but very little is put into practice on the campus. As referenced by Ahern's "plan to fail" method, college campuses are one of the few places where it is acceptable to fail with little consequence (2014).

Considering what the world is learning about alternative working environments during the unprecedented COVID-19 response, there could be a major change in working environments and associated developments on our horizon. If this shift reduces the need for large offices and increases work from home, then the new trajectory of development may be further refined into smaller mixed-use villages. This new development style may be more similar to campus environments. This is all the more reason to use higher education campuses as a place to increase the testing, learning and adapting to new methods of planning and land development that leverage both ecosystem services and the associated metrics, which support sustainable development and resiliency.

7.1 Conclusion: Disconnect Between Research & Application

The science and research being conducted on academic side of campuses does not seem to align with the action of planning and implementation on the administrative side of higher education. Based on the literature review, there is clearly a lot of study concerning how to measure ecosystem services, and how to understand the relationship between human health and ecological performance, and much more. Much of this research is conducted on the college and university campuses where the methods should be put to practice.

This dissonance between theory and practice risks creating an apathetic student community, one that believes that no matter what they are learning in schools, the ideas are not really practiced. According to Ryan, students are often frustrated between the classroom lessons they learn about sustainability and the slow adoption of sustainable practices in the "real-world," including on campus (2018).

Given their pivotal role in society higher education institutions have the potential to support a societal transition towards sustainability (Alshuwaikhat and Abubakar 2008). However, such a role entails that campuses become much more re-oriented or expanded to contribute more explicitly to societal needs and challenges, (Colding and Barthel 2017).

7.2 Recommendations: Connect Goals to Stakeholders & Action Plans

It is not enough to construct a higher education master/physical space plan as a set of aspirational goals to be recognized in the built environmental. Effective planning today requires the consideration of local and regional impacts and stakeholder values and goals at the start of the planning process. Further, higher education institutes should be pushing the envelope in the areas of implementation and engagement so that the students on campus can see and learn from the planned objectives.

Based on the qualitative and quantitative research summarized above, higher education seems to be stuck at the goal stage of planning, particularly as it relates to applying ecosystem service concepts to planning. (The exception is that of stormwater management practices and stated metrics.) This means that, at least on these eight campuses, the living learning laboratory or campus-as-mini-city ideals envisioned in so many research articles are not being realized.

What is missing are the actionable steps to enable the thorough execution of the plan. These steps must be developed with stakeholders who the plan will actually impact on a daily basis. On a higher education campus this includes facility operators, to develop realistic implementation practices, as well as professors and researchers, to enable applied learning and applied research connections. Planning professionals must push ourselves towards mastering what Berke and Godschalk refer to as “the good ness of plans” (2009). Jeffrey D. Sachs said it best in “The Age of Sustainable Development”:

> “Stating a goal is merely the first step of implementing a plan of action. There must be good policy design to implement that program of action. …There must be new

institutions to help implement that goal. And when outcomes occur, they must be measured and strategies must be rethought and adapted in a continuing loop of feedback...” (2015, 491).

7.3 Future Implications

The healthy existence of humans on planet earth will require a broader application of ecosystem services to planning. As issues around sustainability broaden to include equity, resiliency, transportation, biodiversity and more, it will be evermore important to include the full valuation of ecosystem services. Higher education has the unique opportunity to lead in this area and that leadership could very well change the course of humanity’s current, dire trajectory.

CHAPTER 8. SUPPORTING DOCUMENTATION

APPENDIX A. SCORING SHEET GUIDE

GENERAL CONCEPTS OF ECOSYSTEM SERVICES (ES):

1. SPECIFIC/NON-SPECIFIC: Specific ES Included?
    a. Specific: Are there requirements in the plan(s) for specific services provided by nature which provide value back to humans mentioned in the plans?
    b. Non-specific: The natural process attempted to be maintained or developed is mentioned, but there is no direct mention of human health or environmental performance, (the "WHY" is not included)
2. HUMAN HEALTH:
    a. (y/n) Does the plan specifically mention how ES can positively impact human health?
3. ENVIRONMENTAL PERFORMANCE:
    a. (y/n) If yes, this leads down to second scored category- *Depth of Application*.

DEPTH OF APPLICATION:

4. OVERALL vs SINGULAR:
    a. Singular Specific green infrastructure applications, but not within the context of natural or naturalized ecosystems
    b. Overall Ecosystem Health = Macro: Overall ecosystem health or contribution to ecosystem/ecological health system-wide environmental performance is a stated in the goals or outcome which references ES.
        i. Six areas of ecosystem health: air quality; soil structure; energy and material cycling; water quality; habitat and species diversity; ecosystem resilience (Tzoulas et al. 2007).
5. SPATIAL CONNECTIVITY:
    a. Spatial connectivity, multi-functionality, and scale are integral elements for enhancing what ecosystem services can deliver in built landscapes.
6. LOCAL/REGIONAL CONSIDERATIONS: Local Definitions Considered/Created? Referenced in multiple plan evaluation studies:
    a. Regional and community plans "aim to (a) provide a vision to steer the long-term development of municipalities and (b) define policies to steer local development towards achieving this vision" (Rudolph).

EFFECTIVNESS & IMPLENTATION

7. ENGAGEMENT: Where any of the below mentioned as specific needs or requirements in the plan(s)?
    a. Education/Research Engagement/Living Learning Lab
    b. Signage/Communication Plans

c. Community Outreach

8. METRICS: (Of Ecosystem Services)
    a. Do they exist? If so, to what extent? In only one section of the plan(s) or throughout?
9. METRICS BEYOND ECONOMIC:
    a. Intrinsic valuation- Going beyond only economic valuation.
10. COORDINATED WITH IMPLEMENTION PLAN OR IMPLEMENTING ORGANIZATIONS?
    a. Is there evidence that the school has connected a plan to action? This could be via policies, committees or written guidelines. Could also encompass partnerships with local organizations to support implementation.
11. IMPLEMENATION/OPERATIONALIZED:
    a. Informal = Only awards/programs published, but no evidence of formalized guidelines or SOPs. This level will receive less points than if formal guidelines or SOPs are included in the plan(s) or published alongside of the plan(s).
    b. Formal – Guidelines and SOPs are specifically recommended in the plan(s)- Ideally are referenced and included in an Index -or- they are published alongside the initial plan(s).

APPENDIX B. RESEARCH EXPENDITURES & RANKING BY INSTITUTE

(Per the National Science Foundation)

Institute	$ in Research Expenditures (2017)	NSF Research Rank	NSF Percentile
Duke University	$1.16B expend)	8	1.8
Yale University	$990M	15	2.5
Georgia Institute of Technology	$977M	24	3.5
University of California, Berkeley	$789M	26	3.8
University of Massachusetts Amherst	$670M	104	12.3
Indiana University, Bloomington	$604M	45	5.8

APPENDIX C. INDEX SCORE SHEETS

Georgia Institute of Technology Index Score Sheet

UNIVERSITY:	Georgia Tech
PLAN(S) TYPE:	Master Plan 2004, Landscape Master Plan, Operational Plans/SOPs

TOTAL SCORE (AVERAGED):	82.20	Scale: 0 - 100

CATEGORY	ATTRIBUTE	SCALE/ RESPONSE TYPE	ANSWER BY PLAN	POINTS AVAILABLE PER ATTRIBUTE	UNIVERSITY ATTRIBUTE SCORE	CATEGORY SCORE	PLAN SPECIFICS
General	Specific Services	y/n	y	25	25	100	
General	Non-Specific	y/n	y	25	25		
General	Human Health	y/n	y	25	25		
General	Environmental Performance	y/n	y	25	25		

CATEGORY	ATTRIBUTE	SCALE	ANSWER BY PLAN	POINTS AVAILABLE PER ATTRIBUTE	UNIVERSITY ATTRIBUTE SCORE	CATEGORY SCORE	PLAN SPECIFICS
Depth	Overall (2x pts), Singular (1x pts)	o/s	o	50, 25	50	100	"Performance landscape" and "Carbon Storage"
Depth	Spatial Connectivity & Scale	y/n	y	25	25		Discussion of parts of the whole- Lndscp MP
Depth	Local/ Regional Considerations	y/n	y	25	25		Lessening water impacts of overarching city/region.

UNIVERSITY:	Georgia Tech (continued)
PLAN(S) TYPE:	Master Plan 2004, Landscape Master Plan, Operational Plans/SOPs

(Continued)

Scale: 0 - 100

CATEGORY	ATTRIBUTE	SCALE/ RESPONSE TYPE	ANSWER BY PLAN	POINTS AVAILABLE PER ATTRIBUTE	UNIVERSITY ATTRIBUTE SCORE	CATEGORY SCORE	SCHOOL PLAN SPECIFICS
Effectiveness & Implementation	Communication/ Engagement (3 areas for pts)	c	6.6 - 20	a/b/c	6.6	46.6	Mentioned in 2013 plan, but no evidence of implementation.
Effectiveness & Implementation	Metrics: Some vs. Many (1-2 = 10 pts, 3+ = 20 pts)	s/m/n(one)	s	20	10		Pg 13 landscape MP, "Ecological Performance Reqm'ts"
Effectiveness & Implementation	Metrics Beyond Economic	y/n	y	20	20		See above
Effectiveness & Implementation	Coordinated w/ implementation plan	y/ n	n	20	0		
Effectiveness & Implementation	Implementation/ Operations: Formal (1x pt), Informal (.5x pt), None (0 pt)	f/i/n	i	20, 10	10		PGMS, Tree Team, Landscape Committee, Tree Bank

Duke University Index Score Sheet

UNIVERSITY:	Duke University
PLAN(S) TYPE:	A Campus Master Plan & Updated MP Principles (2012), Landscape Character and Design Guidelines (2012), Sust. Guidelines, and Summary of Strategic Initiatives for Facilities (2008)

TOTAL SCORE (AVERAGED) **57.2**

Scale: 0 - 100

CATEGORY	ATTRIBUTE	ANSWER BY PLAN	POINTS PER ATTRIBUTE	SCALE/ RESPONSE TYPE	ATTRIBUTE SCORE	CATEGORY SCORE	SCHOOL PLAN SPECIFICS
General	Specific Services	n	25	y/n	0	50	
General	Non-Specific	y	25	y/n	25		MP = 2 specific zones for ecological integrity/preservation: “Conservation” & “Open Space”; Sust. Design Frmwrk: "intended to preserve and strengthen Duke’s Identity as a University in the forest"
General	Human Health	n	25	y/n	0		No notation of health outcomes.
General	Environmental Performance	y	25	y/n	25		Vegetation & soil protection zones (Sust. Design Framework)

UNIVERSITY:	Duke University (Continued)

CATEGORY	ATTRIBUTE	ANSWER BY PLAN	POINTS PER ATTRIBUTE	SCALE	ATTRIBUTE SCORE	CATEGORY SCORE	SCHOOL PLAN SPECIFICS

Depth	Overall (2x pts), Singular (1x pts)	o	50, 25	o/s	50	75	"Interrelationship of human & natural systems" is 1 line in the MP Principles.
Depth	Spatial Connectivity & Scale	y	25	y/n	25		Landscape Plan "within overall ecology of the campus"- not beyond.
Depth	Local/ Regional Considerations	n	25	y/n	0		No mention of ES impacts beyond campus.

Effectiveness & Implementation	Communication/ Engagement (3 areas for pts)	c	6.6 - 20	a/b/c	6.6	**CATEGORY SCORE:** 46.6	L3 Opportunities highlighted in Landscape plan
Effectiveness & Implementation	Metrics: Some vs. Many (1-2 = 10 pts, 3+ = 20 pts)	s	20	y/n	10		Price on trees via Tree Replacement fund
Effectiveness & Implementation	Metrics Beyond Economic	n	20	y/n	0		
Effectiveness & Implementation	Coordinated w/ implementation plan	y	20	y/ n	20		BMP = Best Mgmt Practices
Effectiveness	Implementation/Operations: Formal (1x pt), Informal (.5x pt), None (0 pt)	i	20/10/0	f/i/n	10		Tree Management Plan- includes forest stewardship; BMP for ponds and forests emphasized.

Indiana University-Bloomington Index Score Sheet

UNIVERSITY:	Indiana University- Bloomington
PLAN(S) TYPE:	Master Plan (2010), Energy Master Plan(2012), Sub District Master Plan (2018)

SCORE (AVERAGE)	92.2

Scale: 0 - 100

CATEGORY	ATTRIBUTE	ANSWER BY PLAN	POINTS PER ATTRIBUTE	SCALE/ RESPONSE TYPE	ATTRIBUTE SCORE	CATEGORY SCORE	SCHOOL PLAN SPECIFICS
General	Specific vs. Non-specific Services	s	25	s/ns/n(one)	50	100	MP mentions river is biological stormwater treatment and flood accommodation system, (a service). Enhanced water quality; River as habitat conneciton, (a service).
General	Human Health	y	25	y/n	25		"Environmentally sensitive landuse practices...protect the health of citizens on campus". River identified to have a
General	Environmental Performance	y	25	y/n	25		River for stormwater management; Pg 148 detailed riparian benefits.

UNIVERSITY:	Indiana University- Bloomington (continued)

CATEGORY	ATTRIBUTE	ANSWER BY PLAN	POINTS PER ATTRIBUTE	SCALE/ RESPONSE TYPE	ATTRIBUTE SCORE	CATEGORY SCORE	SCHOOL PLAN SPECIFICS
Depth	Overall (2x pts), Singular (1x pts)	o	50, 25	o/s	50	100	River as a focal point of sustainably managed resources; an important habitat connection; Stormwater management
Depth	Spatial Connectivity & Scale	y	25	y/n	25		Bloomington (2 rivers) is at the headwaters and can have significant positive impact on outboud.
Depth	Local/ Regional Considerations	y	25	y/n	25		"Reconnect woods, streams, and other key habitat to larger regional preserves.". Also pg. 144.

CATEGORY	ATTRIBUTE	ANSWER BY PLAN	POINTS PER ATTRIBUTE	SCALE/ RESPONSE TYPE	ATTRIBUTE SCORE	CATEGORY SCORE	SCHOOL PLAN SPECIFICS
Effectiveness & Implementation	Communication/ Engagement (3 areas for pts)	c	6.6 - 20	a/b/c	6.6	76.6	Enhance the "Research & Teaching Preserve"
Effectiveness & Implementation	**Metrics:** Some vs. Many (1-2 = 10 pts, 3+ = 20 pts)	m	20	s/m/n(one)	20		All related to trees. Metrics on Air Quality, Carbon Sequestration, Stormwater Runoff.
Effectiveness & Implementation	Metrics Beyond Economic	y	20	y/n	20		Cultural services, pg 144MP
Effectiveness & Implementation	ES coordinated w/ implemenation plan	y	20	y/ n	20		Detailed mainenance plans are reccomended for bothlandscape and sanitary sewer/stormwater initiatives.
Effectiveness & Implementation	Implemenation/ Operations: Formal (1x pt), Informal (.5x pt), None (0 pt)	i	20/10/0	f/i/n	10		Numerous implementation strategies under "Sustain. Principle Recommendations", page 121 and beyond; Pg 147, 148.

Yale University Index Score Sheet

UNIVERSITY:	Yale
PLAN(S) TYPE:	Yale Sustainability Plan 2025 (published 2017); CMP 2000, MP Framework Update 2009.

TOTAL SCORE (AVERAGE	86.11

Scale: 0 - 100

CATEGORY	ATTRIBUTE	ANSWER BY PLAN	POINTS AVAILABLE	SCALE/ RESPONSE TYPE	ATTRIBUTE SCORE	CATEGORY SCORE	SCHOOL PLAN SPECIFICS
General	Specific vs. Non-specific Services	s	25	s/ns/n(one)	50	100	Landscape Plan specifically calls out ES. But, not comprehensive in current plng docs. Urban meadows and raingardens througout campus
General	Human Health	y	25	y/n	25		Recognizing human and ecological health connections in Sust. Plan.
General	Environmental Performance	y	25	y/n	25		Above services (I7) support stormwater and biodiversity

CATEGORY	ATTRIBUTE	ANSWER BY PLAN	POINTS AVAILABLE	SCALE/ RESPONSE TYPE	UNIVERSITY ATTRIBUTE SCORE	CATEGORY SCORE	SCHOOL PLAN SPECIFICS
Depth	Overall (2x pts), Singular (1x pts), none	o	50, 25	o/s/n(one)	50	75	In Sust. Plan: Green Infr.-specif to stormwater mgmt. = urb heat island, groundwater recharge, more
Depth	Spatial Connectivity & Scale	n	25	y/n	0		Never discussed in existing docs.
Depth	Local/ Regional Considerations	y	25	y/n	25		Regional impacts discussed in Sust. Plan and Stormwater Mgmt plan

UNIVERSITY:	Yale (continued)

CATEGORY	ATTRIBUTE	ANSWER BY PLAN	POINTS AVAILABLE	SCALE/ RESPONSE TYPE	UNIVERSITY ATTRIBUTE SCORE	CATEGORY SCORE	SCHOOL PLAN SPECIFICS
Effectiveness & Implementation	Communication/ Engagement (3 areas for pts)	b	6.6 - 20	a/b/c/d	13.32	83.32	Living Lab = "Landscape Lab" and 5 acre watershed test site for "westcampus.yale.edu". "Promote stormwater research" specifically mentioned in Stormwater Mgmt Plan; Partnerships with the City and with downtown groups to implement. (Community engagement)
Effectiveness & Implementation	Metrics: Some vs. Many (1-2 = 10 pts, 3+ = 20 pts)	s	20	m/s/n(one)	10		different ones related to disconnection from discharge and management of rainwater using LID; Landscape: No metrics mentioned. But, current outcomes are the
Effectiveness & Implementation	Metrics Beyond Economic	y	20	y/n	20		Water quality...Human health benefits vaguely mentioned in Sust. Plan.
Effectiveness & Implementation	Coordinated w/ implemenation plan	y	20	y/ n	20		IDs collaboration b/w academic and operations to learn, implement and improve. Also partenring w/ City watershed.
Effectiveness & Implementation	Implemenation: Formal (1x pt), Informal (.5x pt), None (0 pt)	f	20/10/0	f/i/n	20		The Landscape Mgmt Plan and Stormwater Mgmt Plan are focused on Implemenation.

Purdue University Index Score Sheet

UNIVERSITY:	Purdue
PLAN(S) TYPE:	Master Plan (2009), Sustainability Strategic Plan (2010)

SCORE AVERAGE	57.2

Scale: 0 - 100

CATEGORY	ATTRIBUTE	ANSWER BY PLAN	POINTS PER ATTRIBUTE	SCALE/ RESPONSE TYPE	ATTRIBUTE SCORE	CATEGORY SCORE	SCHOOL PLAN SPECIFICS
General	Specific vs. Non-specific Services	s	25	s/ns/n(one)	50	75	SW Design Guide discusses ecosystem services specifically
General	Human Health	n	25	y/n	0		Not a prominent compoment of any of the plans' goals or initiatives.
General	Environmental Performance	y	25	y/n	25		MP: "Open Space" = green infrastructure and naturalized landscape; Stormwater Mgmt for water quality; Native planting initiative (published/connected to Sustainability Plan) recognizes multiple ES outcomes.

UNIVERSITY:	Purdue (continued)

CATEGORY	ATTRIBUTE	ANSWER BY PLAN	POINTS AVAILABLE PER ATTRIBUTE	SCALE/ RESPONSE TYPE	UNIVERSITY ATTRIBUTE SCORE	CATEGORY SCORE	SCHOOL PLAN SPECIFICS
Depth	Overall (2x pts), Singular (1x pts), none	s	50, 25	o/s/n(one)	25	50	Any mention of ES is very specific to stormwater management and the outcome on water quality.
Depth	Spatial Connectivity & Scale	n	25	y/n	0		Nothing found about scale or connectivity.
Depth	Local/ Regional Considerations	y	25	y/n	25		Regional water supply support mentioned in SWMP.
Effectiveness & Implementation	Communication/ Engagement (3 areas for pts)	c	6.6 - 20	a/b/c/d	6.6	CATEGORY SCORE: 46	MP: Horticulture Park (pg 82) mentions that it's a learning environment.
Effectiveness & Implementation	Metrics: Some vs. Many (1-2 = 10 pts, 3+ = 20 pts)	s	20	m/s/n(one)	10		The SWMP has some measurable goals.
Effectiveness & Implementation	Metrics Beyond Economic	n	20	y/n	0		Sustain plan has metrics but very vauge, not truly measurable and not associated with ES.
Effectiveness & Implementation	Coordinated w/ implemenation plan	y	20	y/ n	20		Best Management Practices are mentioned in Chp 3 of SWMP, but the entire thing is not readily
Effectiveness & Implementation	Implemenation/Operations: Formal (1x pt), Informal (.5x pt), None (0 pt)	i	20/10/0	f/i/n	10		Best Management Practices are mentioned in Chp 3 of SWMP, but the entire thing is not readily published. Have to know it exists and

University Colorado-Boulder Index Score Sheet

UNIVERSITY:	UC Boulder
PLAN(S) TYPE:	Master Plan Boulder (2011)

SCORE AVERAGE **61.11**

Scale: 0 - 100

CATEGORY	ATTRIBUTE	ANSWER BY PLAN	POINTS PER ATTRIBUTE	SCALE/ RESPONSE TYPE	ATTRIBUTE SCORE	CATEGORY SCORE	SCHOOL PLAN SPECIFICS
General	Specific vs. Non-specific Services	ns	25	s/ns/ n(one)	25	75	Non-specific biophilia and using bioswales/mimic nat'l systems for stormwater mgmt practices.
General	Human Health	y	25	y/n	25		Buiding (Sustain Plan)- captialize on biophilic design to promote well-being; Open space creates psychological/sociological connections.
General	Environmental Performance	y	25	y/n	25		Throughout building specs in Sustain. Section of MP.

CATEGORY	ATTRIBUTE	ANSWER BY PLAN	POINTS PER ATTRIBUTE	SCALE/ RESPONSE TYPE	ATTRIBUTE SCORE	CATEGORY SCORE	SCHOOL PLAN SPECIFICS
Depth	Overall (2x pts), Singular (1x pts), none	s	50, 25	o/s/n(one)	25	CATEGORY SCORE: 25	Singular in the Sustain. MP. Systems are recognized in the "Land/Facilities MP", but are focused on design/views, not services.
Depth	Spatial Connectivity & Scale	n	25	y/n	0		Mentions microclimates... Recognizes natrl areas provide many benefits, but not "service" focused.
Depth	Local/ Regional Considerations	n	25	y/n	0		Not mentioned as it relates to ecology/environment.

UNIVERSITY:	UC Boulder (continued)

CATEGORY	ATTRIBUTE	ANSWER BY PLAN	POINTS PER ATTRIBUTE	SCALE/ RESPONSE TYPE	UNIVERSITY ATTRIBUTE SCORE	CATEGORY SCORE	SCHOOL PLAN SPECIFICS
Effectiveness & Implementation	Communication/ Engagement (3 areas for pts)	b	6.6 - 20	a/b/c/d	13.32	83.32	Wetland ponds accommodate "nature study" and stormwater mgmt; L3 mentioned, but not entirely related to ecology; Community outreach when developing. Again, not entirely ecology based.
Effectiveness & Implementation	Metrics: Some vs. Many (1-2 = 10 pts, 3+ = 20 pts)	s	20	m/s/ n(one)	10		Mention of some stormwater retention goals only.
Effectiveness & Implementation	Metrics Beyond Economic	y	20	y/n	20		Not very specific to ES; References LEED and STARS guidelines.
Effectiveness & Implementation	Coordinated w/ implemenation plan	y	20	y/ n	20		There is a mention of Best Practices.
Effectiveness & Implementation	Implemenation/Operations: Formal (1x pt), Informal (.5x pt), None (0 pt)	f	20/10/0	f/i/n	20		MP Land & Facilities discusses continuing current Turf Task Force (TTF) and Integrated Pest Management (IPM) plans; Best

University California- Berkeley Index Score Sheet

UNIVERSITY:	UC Berkeley
PLAN(S) TYPE:	Framework for Capital Investment (2003); Landscape Master Plan (2004), Long Range Devlp't Plan (2005)

SCORE AVERAGE **63.87**

Scale: 0 - 100

CATEGORY	ATTRIBUTE	ANSWER BY PLAN	POINTS PER ATTRIBUTE	SCALE/ RESPONSE TYPE	ATTRIBUTE SCORE	CATEGORY SCORE	SCHOOL PLAN SPECIFICS
General	Specific vs. Non-specific Services	ns	25	s/ns/n(one)	25	75	MP: Preservation zones ID, but only "biotic integrity" listed as a benefit/service.
General	Human Health	y	25	y/n	25		Campus open space referenced as a venue for relaxation and peaceful counterpoint to urbanization (LRDP)
General	Environmental Performance	y	25	y/n	25		LRDP: Restore native vegetation & hydrology to mitigate flood risk.
Depth	Overall (2x pts), Singular (1x pts), none	s	50, 25	o/s/ n(one)	25	CATEGORY SCORE: 50	Bioswales were mentioned, but not a systems-approach to providing services
Depth	Spatial Connectivity & Scale	n	25	y/n	0		Only mentioned in the context of beauty. Not in functional outcomes (services).
Depth	Local/ Regional Considerations	y	25	y/n	25		Not specific to ES- more in general that a "park setting" is an amenity for the city.

UNIVERSITY:	UC Berkeley (continued)

CATEGORY	ATTRIBUTE	ANSWER BY PLAN	POINTS PER ATTRIBUTE	SCALE/ RESPONSE TYPE	UNIVERSITY ATTRIBUTE SCORE	CATEGORY SCORE	SCHOOL PLAN SPECIFICS
Effectiveness & Implemenation	Communication/ Engagement (3 areas for pts)	c	6.6 - 20	a/b/c/d	6.6	66.6	L3 for Strawberry Creek and Campus Groves.
Effectiveness & Implemenation	Metrics: Some vs. Many (1-2 = 10 pts, 3+ = 20 pts)	n	20	m/s/ n(one)	0		No specific metrics to measure progress against.
Effectiveness & Implemenation	Metrics Beyond Economic	y	20	y/n	20		Lots of intrinsic value placed on the open spaces.
Effectiveness & Implemenation	Coordinated w/ implemenation plan	y	20	y/ n	20		plans, etc. Plus MP aligns to Lndscp MP
Effectiveness	Implemenation/Operations: Formal (1x pt), Informal (.5x pt), None (0 pt)	f	20/10/0	f/i/n	20		Informal- they give principles to be followed for renewal, but don't mention a specific BMP, SOP, etc.

University Massachusetts-Amherst Index Score Sheet

UNIVERSITY:	U. Mass-Amherst
PLAN(S) TYPE:	Masterplan 2012, Sustainability Update 2015

SCORE AVERAGE **67.20**

Scale: 0 - 100

CATEGORY	ATTRIBUTE	ANSWER BY PLAN	POINTS PER ATTRIBUTE	SCALE/ RESPONSE TYPE	ATTRIBUTE SCORE	CATEGORY SCORE	SCHOOL PLAN SPECIFICS
General	Specific vs. Non-specific Services	s	25	s/ns/ n(one)	50	75	Beauty and cultural value (intrinsic) dominate the 2012 plan; Some add'l stormwater value highlighted in Susain Plan 2015.
General	Human Health	n	25	y/n	0		
General	Environmental Performance	y	25	y/n	25		The Sustain Chp. Refers to a Landscape MP in progress.
Overall	# of Services		face value	face value			Not included in index. Noted.

CATEGORY	ATTRIBUTE	ANSWER BY PLAN	POINTS AVAILABLE	RESPONSE TYPE	ATTRIBUTE SCORE	CATEGORY SCORE	SCHOOL PLAN SPECIFICS
Depth	Overall (2x pts), Singular (1x pts), none	o	50, 25	o/s/ n(one)	50	100	Overall only for watershed. "Water quality"
Depth	Spatial Connectivity & Scale	y	25	y/n	25		"Working landscape" and "district level stormwater solution" to support regional watershed
Depth	Local/ Regional Considerations	y	25	y/n	25		Mentions the greenspace connectivity and value as an amenity to the region;

UNIVERSITY:	U. Mass-Amherst (continued)

CATEGORY	ATTRIBUTE	ANSWER BY PLAN	POINTS PER ATTRIBUTE	SCALE/ RESPONSE TYPE	UNIVERSITY ATTRIBUTE SCORE	CATEGORY SCORE	SCHOOL PLAN SPECIFICS
Effectiveness & Implemenation	Communication/ Engagement (3 areas for pts)	c	6.6 - 20	a/b/c/d	6.6	26.6	Only living lab mentioned, and loosely; Not specific to ES. Sustain Plan mentions additions of "educational landscapes" including a permaculture garden.
Effectiveness & Implemenation	Metrics: Some vs. Many (1-2 = 10 pts, 3+ = 20 pts)	s	20	m/s/ n(one)	10		Slow the Flow has significant metrics. But, it's only loosely referenced in the official MP;
Effectiveness & Implemenation	Metrics Beyond Economic	n	20	y/n	0		Nothing official in any MP documents.
Effectiveness & Implemenation	Coordinated w/ implemenation plan	n	20	y/ n	0		Some reccos of guidelines mentioned in Sustain Chp, but nothing formal.
Effectiveness	ions: Formal (1x pt), Informal (.5x pt), None (0 pt)	i	20/10/0	f/i/n	10		

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